

PRESYMMETRY BEYOND THE STANDARD MODEL

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We go beyond the Standard Model guided by presymmetry, the discrete electroweak quark–lepton symmetry hidden by topological effects which explain quark fractional charges as in condensed matter physics. We show that partners of the particles of the Standard Model and the discrete symmetry associated with this partnership appear as manifestations of a residual presymmetry in the sense of Ekstein and its extension from matter to forces. This duplication of the spectrum of the Standard Model keeps spin and comes nondegenerated about the TeV scale.

Keywords: Beyond Standard Model; partner particles; prequarks; preleptons; residual presymmetry; hidden sector.

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1. Introduction

In the phenomenological successful Standard Model (SM), the number of fermion generations is not fixed by any symmetry principle. The famous question “who order that” of I. I. Rabi when the muon was identified in the late ’40s of the last century, has been generalized to why are there three families, but remains unanswered at the level of the SM. Moreover, constraints from high precision experiments do not prohibit new sequential or nonsequential families, but instead provide only restrictions on their mass spectrum. The resulting masses for the new sequential leptons should make easy their detection with neutrino pair productions being the interesting signals. Nonsequential quarks and leptons, partners of the SM ones, should be produced in pairs if they are protected by some new discrete symmetry. These partner particles, although more difficult to understand, are favored by the existence of dark matter in the universe. However, with so many quark–lepton family replicas it is conceivable that the symmetries ordering the known fermion generations, on the one hand, and the lightest new partner particles, on the other hand, be related to each other in a unified description. Ultimately, they would be part of the same family replication problem.

Partners of the SM particles have been suggested by various new physics models motivated by different puzzling aspects of the SM. One of these is the hierarchy problem,¹ i.e. the disparity between the energy scale where electroweak symmetry breaking takes place and the scale of new physics if the SM is viewed as an effective

theory with a cutoff that can be as low as a few TeV. This discrepancy manifests itself through quadratic divergences on the cutoff affecting the SM Higgs mass, required to be of a few hundred GeV by electroweak precision measurements. The most popular approaches to solve this naturalness problem are directed by the supersymmetric models,^{2,3} in which fundamental light Higgs bosons are maintained; the little Higgs models,^{4,5} in which the light Higgs boson also appears elementary but is identified as a pseudo-Goldstone boson in a scenario where, however, the problem is only pushed to higher scales; and the extra dimension models,⁶ in which a fundamental Planck scale close to the electroweak scale is advanced, so that the ultimate ultraviolet cutoff is around the TeV scale, protecting the Higgs mass from divergent radiative corrections. To evade all constraints from electroweak precision data, these proposals require the existence of heavy partners of the SM particles at the Terascale and an associated extra Z_2 symmetry. This discrete symmetry is R -parity in supersymmetric models,^{7,8} T -parity in little Higgs models,^{9–11} and KK -parity in the so-called universal extra dimension models¹² which, however, do not directly address the fine-tuning issue. Nevertheless, it should be stressed that the hierarchy problem is not indeed a trouble with the SM itself; it may not exist if there is no new physics between the electroweak scale and the Planck scale.¹³ On the other hand, the idea of unification of the SM gauge couplings is degraded in little Higgs models and extra dimension models.

Another puzzling feature of the SM is the left–right asymmetry of its weak interactions. Mirror matter models address this problem by introducing P -parity and mirror partners for all SM particles,¹⁴ although this parity symmetry is violated in each electroweak sector and renormalizable gauge-invariant interactions between standard and mirror particles are possible mainly through mixing terms involving the standard and mirror Higgs fields. The physical Higgs boson can then decay into mirror particles, i.e. invisibly, through all possible mechanisms of the Higgs boson production itself, giving distinctive signatures of the mirror world that can be tested.

There is still no experimental confirmation of any of these views on nature, whose symmetries do not relate the partner particles with the fermion family problem either. Hence, with the emerging CERN–LHC era, it is important to explore any other well-motivated scenario that gives rise to observable partners associated with an underlying discrete symmetry which be somehow connected with the origin of the triplication of fermion families. In this letter we report achievements from models which address in the first place the question of the quark–lepton symmetry, exhibited plainly in the electroweak gauge sector of the SM when Dirac neutrinos are included.

The discrete quark–lepton symmetry has recently been extended from the weak to electromagnetic interactions by considering topological effects as in condensed matter physics to account for quark fractional charges.^{15–17} The quark–lepton charge relations are explained by adding to the SM with Dirac neutrinos the new hidden quark (lepton) states of prequarks (preleptons) with integer (fractional) charges as in leptons (quarks). By exploiting the discrete prequark–lepton (quark–

prelepton) charge symmetry, the so-called presymmetry,^a several other riddles of the SM have been understood, such as the charge quantization, confinement of fractional charges and triplication of quark-lepton families, relating the number of generations with the number of colors. The gauge anomalies associated with prequarks (preleptons) lead to the appearance of a topological charge, which induces the fractional charges and the physical quark (lepton) states.¹⁵ The universality of weak interactions of quarks and leptons also holds at the level of prequarks and preleptons, with weak topological charges being generated upon ones and the others.

Electroweak presymmetry is hidden at the level of standard quarks and leptons. Due to its topological character, however, presymmetry is independent of the energy scale and therefore underlies any new physics beyond the SM with Dirac neutrinos, which usually invokes new matter and interactions. In this letter we address ourselves to the possibility that traces of this symmetry may show up at low energies from a symmetric expansion of the SM gauge symmetry $SU(3)_q \times SU(2)_{q\ell} \times U(1)_Y$. Specifically, we consider the well-motivated symmetric model $SU(3)_q \times SU(3)_{\tilde{q}} \times SU(2)_{q\tilde{\ell}} \times SU(2)_{\tilde{q}\ell} \times U(1)_Y \times \tilde{P}$ of standard and exotic quarks and leptons of the same 1/2 spin,²⁰ where the exotic partners are denoted by tildes and \tilde{P} is a Z_2 discrete symmetry of the full Lagrangian under the exchange of the new particles and the SM particles that constrains the bare color as well as weak coupling constants to be equal.

Our aim in this letter is to show that the exotic partners and the associated \tilde{P} -symmetry, named exotic symmetry, appear as manifestations of a remaining presymmetry in the sense of Ekstein^{18,19} and its extension from matter to forces. This will mean to add significant new understanding to the physics of both presymmetry as presented in Ref. 15 at the SM level and the exotic symmetry in the exotic doubling of the SM proposed in Ref. 20. In the scenario of the above expanded gauge symmetry, exotic symmetry involves new physics that can be close to the electroweak scale. In fact, it has been shown that at the level of normalized quarks and leptons, all the features of the SM are retained even if the new neutral and charged weak bosons were relatively light. These nonstandard bosons have the signature of exotic symmetry but they do not exhibit the universality of the interactions of the standard ones, so that a lower bound for their masses can be set.²⁰ Also, the fermion partners fit the electroweak data with mass below 1 TeV and are stable if the fermion numbers are separately conserved. From the viewpoint of the hierarchy problem mentioned above, the duplication of the SM with Dirac neutrinos under the exotic symmetry remains natural at the electroweak scale, deferring the fine-tuning problem of any other gauge symmetry breaking at higher energies.

Our prime motivation to prompting new physics beyond the SM with Dirac

^aHere we clarify the concept of (charge) presymmetry introduced within the framework of quarks and leptons along the idea of presymmetry of Ekstein^{18,19} inasmuch as we have, as shown in Sec. 2, residual (charge) symmetry transformations in spite of the existence of symmetry-breaking dynamical effects.

neutrinos by duplicating gauge groups with quark and lepton type of families, as done in Ref. 20, is indeed to generate a residual presymmetry in the sense of Ekstein, so avoiding the use against the model of the often-cited principle known as Occam’s razor^b: “Entities should not be multiplied unnecessarily.” In fact, if no extension of the SM with Dirac neutrinos is considered, presymmetry remains as a hidden feature of the SM with no direct implications to be observed. Therefore, by Occam’s razor it would have to be eliminated from the SM, expecting that its indirect successful implications¹⁵ would be explained differently by some other physics beyond the SM. In particular, the quark–lepton charge symmetries presented in Refs. 15–17 in support of presymmetry should be taken as accidental and not real, which is difficult to accept. Hence, doubling of the SM particles with a residual presymmetry becomes a presymmetry requirement.

A second motivation for this doubling of the SM is to expand presymmetry from matter to forces. Since presymmetry seems to be a relevant hidden symmetry of nature and *transverse to everything*, it is feasible that this discrete symmetry partially or completely extends to the forces of the SM, so that symmetric fermions interact with symmetric gauge bosons and the corresponding gauge symmetry is doubled. Also, it is conceivable that the replication of fermionic families be accompanied of a replication of bosonic force carriers, with a common underlying symmetry ordering their occurrence.

A third motivation is to extend the discrete symmetry from the electroweak to the strong sector, i.e. to have presymmetry for the full Lagrangian of fundamental interactions, therefore acquiring more significance with a strong influence on the course of the new physics beyond the SM. Furthermore, from the point of view of the presumptive existence of new generations, presymmetry requires that the new quark families be nonsequential, which demands a duplication of the color gauge group $SU(3)$. This suggests in turn a duplication of the electroweak group $SU(2) \times U(1)$. The extra quark and lepton partners avoid in an obvious way any anomaly problem in the duplication of the gauge groups. Besides, if new quark–lepton families are found, the topological formalism to explain fractional charges also applies to quark partners, so that the symmetry associated with their existence has to be connected with presymmetry.

A fourth motivation comes from the fact that though standard quarks and leptons are subject to universality in the Lagrangian of weak interactions, their partners should not because these are not sequential fermions. It is quite possible that weak universality is only a low-energy property of standard quarks and leptons. This can be realized by duplicating the weak gauge group.²⁰

All of the above provides reasons to expect that at least a piece of the new physics that can be explored around the TeV scale is a manifestation of presymmetry. In the context of the extended gauge model taken up in this letter, this is effected through the relation between presymmetry and the exotic symmetry. On the other

^bFor a recent use of the Occam’s razor principle, see Ref. 21.

hand, the single doubling of the list of the SM particles anticipated by presymmetry does not contravene other models that also introduce partner particles. It does not spoil, for instance, that suggested by supersymmetry. Moreover, these doublings of the particle spectrum may be compatible. Their motivations are after all quite different: supersymmetry attacks a mass problem, whereas presymmetry addresses a charge question.

The letter is organized as follows. The presymmetric expansion of the SM in the scenario of hidden prequarks and leptons is presented in Sec. 2 and that in terms of quarks and hidden preleptons is given in Sec. 3, showing that the exotic partners and the associated exotic symmetry appear as manifestations of a residual presymmetry and its extension from matter to forces. Phenomenological implications for searches of new physics about the TeV scale are discussed in Sec. 4. Conclusions are drawn in Sec. 5.

2. Presymmetric Extension of the SM with Prequark Partners

We start by describing the fermionic sector of the model with hidden integer-charged prequarks underlying fractionally-charged quarks. It is an enlargement to the extended gauge group of the topological approach to charge structure of quarks developed at the SM level.^{16,17}

The spectrum of physical fermions includes quarks, leptons with Dirac neutrinos, and their exotic partners. Their assignments under the extended gauge group $SU(3)_q \times SU(3)_{\tilde{q}} \times SU(2)_{q\tilde{\ell}} \times SU(2)_{\tilde{q}\tilde{\ell}} \times U(1)_Y$ are

$$\begin{aligned}
 q_{nL}^i &\sim \left(3, 1, 2, 1, \frac{1}{3}\right), & \tilde{q}_{nL}^i &\sim \left(1, 3, 1, 2, \frac{1}{3}\right), \\
 u_{nR}^i &\sim \left(3, 1, 1, 1, \frac{4}{3}\right), & \tilde{u}_{nR}^i &\sim \left(1, 3, 1, 1, \frac{4}{3}\right), \\
 d_{nR}^i &\sim \left(3, 1, 1, 1, -\frac{2}{3}\right), & \tilde{d}_{nR}^i &\sim \left(1, 3, 1, 1, -\frac{2}{3}\right), \\
 \ell_{nL} &\sim (1, 1, 1, 2, -1), & \tilde{\ell}_{nL} &\sim (1, 1, 2, 1, -1), \\
 \nu_{nR} &\sim (1, 1, 1, 1, 0), & \tilde{\nu}_{nR} &\sim (1, 1, 1, 1, 0), \\
 e_{nR} &\sim (1, 1, 1, 1, -2), & \tilde{e}_{nR} &\sim (1, 1, 1, 1, -2),
 \end{aligned} \tag{1}$$

where i denotes the color degree of freedom, n refers to the three generations, and the numbers in brackets describe the gauge-group transformation properties.

The hidden prequarks and their exotic partners, here denoted by hats, have the

following transformation qualities under the gauge group:

$$\begin{aligned}
\hat{q}_{nL}^i &\sim (3, 1, 2, 1, -1), & \hat{\tilde{q}}_{nL}^i &\sim (1, 3, 1, 2, -1), \\
\hat{u}_{nR}^i &\sim (3, 1, 1, 1, 0), & \hat{\tilde{u}}_{nR}^i &\sim (1, 3, 1, 1, 0), \\
\hat{d}_{nR}^i &\sim (3, 1, 1, 1, -2), & \hat{\tilde{d}}_{nR}^i &\sim (1, 3, 1, 1, -2).
\end{aligned} \tag{2}$$

In this scenario of prequarks, leptons, and exotic partners, the gauge anomalies produced by the integer hypercharge of ordinary and exotic prequarks are cancelled by incorporating local counterterms with Chern–Simons configurations of gauge fields, as it is done for the SM gauge group $SU(3)_q \times SU(2)_{q\ell} \times U(1)_Y$.^{16,17}

Thus, on the one hand, the electroweak part of the bare Lagrangian remains invariant under the extended \hat{P} -presymmetry transformation, where ordinary (exotic) prequark multiplets of a given color are exchanged with ordinary (exotic) lepton multiplets according to

$$\begin{aligned}
\hat{q}_{nL}^i &\leftrightarrow \ell_{nL}, & \hat{u}_{nR}^i &\leftrightarrow \nu_{nR}, & \hat{d}_{nR}^i &\leftrightarrow e_{nR}, \\
\hat{\tilde{q}}_{nL}^i &\leftrightarrow \tilde{\ell}_{nL}, & \hat{\tilde{u}}_{nR}^i &\leftrightarrow \tilde{\nu}_{nR}, & \hat{\tilde{d}}_{nR}^i &\leftrightarrow \tilde{e}_{nR},
\end{aligned} \tag{3}$$

and $W_q^a \leftrightarrow W_{\tilde{q}}^a$ for the gauge bosons of $SU(2)_{q\tilde{\ell}}$ and $SU(2)_{\tilde{q}\ell}$, respectively. This discrete symmetry requires that their gauge coupling constants be equal.

On the other hand, there is still invariance under the electroweak $\hat{\tilde{P}}$ -presymmetry transformation, where ordinary (exotic) prequark multiplets of a given color are exchanged with exotic (ordinary) leptons:

$$\begin{aligned}
\hat{q}_{nL}^i &\leftrightarrow \tilde{\ell}_{nL}, & \hat{u}_{nR}^i &\leftrightarrow \tilde{\nu}_{nR}, & \hat{d}_{nR}^i &\leftrightarrow \tilde{e}_{nR}, \\
\hat{\tilde{q}}_{nL}^i &\leftrightarrow \ell_{nL}, & \hat{\tilde{u}}_{nR}^i &\leftrightarrow \nu_{nR}, & \hat{\tilde{d}}_{nR}^i &\leftrightarrow e_{nR},
\end{aligned} \tag{4}$$

keeping all the gauge fields unchanged. This discrete symmetry is equivalent to the electroweak presymmetry at the level of the SM.

As shown in Fig. 1(a), the Z_2 symmetries \hat{P} and $\hat{\tilde{P}}$ introduce the exotic \tilde{P} -symmetry defined by $\tilde{P} = \hat{\tilde{P}}\hat{P} = \hat{P}\hat{\tilde{P}}$, under which ordinary and exotic prequarks and leptons are transformed as follows:

$$\begin{aligned}
\hat{q}_{nL}^i &\leftrightarrow \hat{\tilde{q}}_{nL}^i, & \hat{u}_{nR}^i &\leftrightarrow \hat{\tilde{u}}_{nR}^i, & \hat{d}_{nR}^i &\leftrightarrow \hat{\tilde{d}}_{nR}^i, \\
\ell_{nL} &\leftrightarrow \tilde{\ell}_{nL}, & \nu_{nR} &\leftrightarrow \tilde{\nu}_{nR}, & e_{nR} &\leftrightarrow \tilde{e}_{nR},
\end{aligned} \tag{5}$$

and $W_q^a \leftrightarrow W_{\tilde{q}}^a$ for the gauge bosons, with equal gauge couplings. Moreover, now the whole bare Lagrangian of electroweak and strong interactions is invariant under the exotic \tilde{P} -symmetry if we include the transformation $G_q^b \leftrightarrow G_{\tilde{q}}^b$ for the gluons of $SU(3)_q$ and $SU(3)_{\tilde{q}}$, and make equal their couplings. In this manner, presymmetry becomes extended from matter to forces, as demanded.

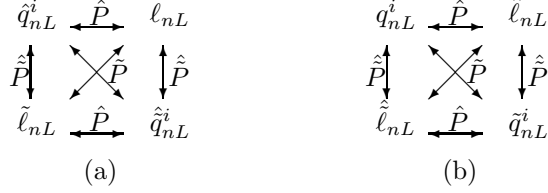


Fig. 1. Electroweak presymmetric transformations of fermion doublets in the scenario of (a) prequarks and (b) preleptons.

Ordinary and exotic quarks of fractional charge are generated from ordinary and exotic prequarks of integer charge through universal fractional charge shifts $\Delta Y = 4/3$ induced by integer topological charges.^{15–17} In this mechanism, \hat{P} and $\tilde{\hat{P}}$ presymmetries are broken. The exotic \tilde{P} -symmetry, however, remains exact. This shows that it can be seen as a manifestation of a remaining presymmetry in the sense of Ekstein^{18,19} and its extension from matter to forces. Its spontaneous breaking occurs because of the gauge symmetry breaking,²⁰ which does not involve charges themselves.

Note that exotic partners are required to have a physical residual presymmetry. If no extension of the SM with Dirac neutrinos is considered, presymmetry remains hidden with no survival of presymmetry relations between observable quarks and leptons.¹⁵ In the same way, the symmetric duplication of the SM proposed in Ref. 20 may appear somewhat contrived if there is no connection with a residual presymmetry.

3. Presymmetric Extension of the SM with Prelepton Partners

The hidden electroweak presymmetry operates in two forms: between prequarks and leptons, and between quarks and preleptons. In the scenario of hidden preleptons and exotic partners, their assignments to the gauge group $SU(3)_q \times SU(3)_{\tilde{q}} \times SU(2)_{q\tilde{\ell}} \times SU(2)_{\tilde{q}\ell} \times U(1)_Y$ are

$$\begin{aligned} \hat{\ell}_{nL} &\sim (1, 1, 1, 2, \frac{1}{3}), & \hat{\tilde{\ell}}_{nL} &\sim (1, 1, 2, 1, \frac{1}{3}), \\ \hat{\nu}_{nR} &\sim (1, 1, 1, 1, \frac{4}{3}), & \hat{\tilde{\nu}}_{nR} &\sim (1, 1, 1, 1, \frac{4}{3}), \\ \hat{e}_{nR} &\sim (1, 1, 1, 1, -\frac{2}{3}), & \hat{\tilde{e}}_{nR} &\sim (1, 1, 1, 1, -\frac{2}{3}). \end{aligned} \quad (6)$$

The preleptonic form of the \tilde{P} -presymmetry transformation in Eq. (3) is set up as

$$\begin{aligned} q_{nL}^i &\leftrightarrow \hat{\ell}_{nL}, & u_{nR}^i &\leftrightarrow \hat{\nu}_{nR}, & d_{nR}^i &\leftrightarrow \hat{e}_{nR}, \\ \tilde{q}_{nL}^i &\leftrightarrow \hat{\tilde{\ell}}_{nL}, & \tilde{u}_{nR}^i &\leftrightarrow \hat{\tilde{\nu}}_{nR}, & \tilde{d}_{nR}^i &\leftrightarrow \hat{\tilde{e}}_{nR}, \end{aligned} \quad (7)$$

and $W_q^a \leftrightarrow W_{\bar{q}}^a$.

In place of the \hat{P} -presymmetry in Eq. (4), we have

$$\begin{aligned} q_{nL}^i &\leftrightarrow \hat{\ell}_{nL}^i, & u_{nR}^i &\leftrightarrow \hat{\nu}_{nR}^i, & d_{nR}^i &\leftrightarrow \hat{e}_{nR}^i, \\ \tilde{q}_{nL}^i &\leftrightarrow \hat{\ell}_{nL}^i, & \tilde{u}_{nR}^i &\leftrightarrow \hat{\nu}_{nR}^i, & \tilde{d}_{nR}^i &\leftrightarrow \hat{e}_{nR}^i, \end{aligned} \quad (8)$$

keeping the gauge fields unchanged.

Instead of the exotic \tilde{P} -symmetry transformation in Eq. (5) we now obtain, as illustrated in Fig. 1(b),

$$\begin{aligned} q_{nL}^i &\leftrightarrow \tilde{q}_{nL}^i, & u_{nR}^i &\leftrightarrow \tilde{u}_{nR}^i, & d_{nR}^i &\leftrightarrow \tilde{d}_{nR}^i, \\ \hat{\ell}_{nL}^i &\leftrightarrow \hat{\ell}_{nL}^i, & \hat{\nu}_{nR}^i &\leftrightarrow \hat{\nu}_{nR}^i, & \hat{e}_{nR}^i &\leftrightarrow \hat{e}_{nR}^i, \end{aligned} \quad (9)$$

together with $W_q^a \leftrightarrow W_{\bar{q}}^a$ and $G_q^b \leftrightarrow G_{\bar{q}}^b$.

Ordinary and exotic leptons of integer charges are generated from ordinary and exotic preleptons of fractional charge in a way similar to that described for quarks from prequarks.¹⁵ The exotic \tilde{P} -symmetry is again explained from a residual presymmetry and its extension to forces, as posed in the Introduction.

4. Phenomenological Implications

The exotic particles with \tilde{P} -symmetry have a phenomenology similar to that of the partner particles in supersymmetric models with R -parity, little Higgs models with T -parity, and universal extra dimension models with KK -parity. Since no partner particles have already been detected, all of these models require symmetry breaking mechanisms in order to give them a mass heavier than that of the SM particles. There exists a large amount of work concerning their implications. For a number of reasons, in particular the elegant solution to the hierarchy problem, the supersymmetric partners appear as the leading candidates to be the expected new particles.³

Some features of our model, however, can make simple its discrimination from the others. A spontaneous breaking of the expanded gauge symmetry and the discrete exotic symmetry $SU(3)_q \times SU(3)_{\bar{q}} \times SU(2)_{q\bar{\ell}} \times SU(2)_{\bar{q}\ell} \times U(1)_Y \times \tilde{P}$ via the Higgs mechanism has been discussed in Ref. 20. It is a renormalizable extension of the SM that includes a Higgs bidoublet and a symmetric duplication of the SM Higgs doublet which produce the breakdown at tree level and make mass of the new particles different from known ones, and heavy enough as to have evaded observation in experiments performed up to now. Although constraints on masses of exotic partners are placed by cosmology and precision electroweak experiments, no fine tuning at the electroweak scale is required. It has been shown that three generations of relatively heavy extra quarks and leptons can fit the data in a two-Higgs-doublet scenario,²² with resulting fermion masses greater than about 100 GeV and smaller than about 1 TeV. Such Higgs doublets are required to implement presymmetry in

the Higgs sector. The pressing mass limit for the lightest Higgs boson is alleviated and the naturalness scale of the electroweak model is ameliorated because the doubling of the SM Higgs doublet can defer the fine-tuning problem to a higher scale, as argued in Ref. 23. Regarding the new exotic weak bosons, these do not have the universality of the interactions of the standard weak bosons, so that lower bounds of a few TeV can be set for their masses.²⁰ And the new exotic gluons, which only bind exotic quarks into exotic hadrons, are massless and have asymptotically free couplings, just like the properties of usual gluons in ordinary hadrons. The finding of a duplication of the spectrum of the SM that keep spins and be nondegenerated and natural enough around the TeV scale would be a strong support for the model.

Nevertheless, to stabilize the hierarchy beyond this scale, even new physics will be required. On the one hand, this would imply to embed the extended gauge model into a supersymmetric model, or a little Higgs model, or an extra dimension model, with the corresponding proliferation of elementary gauge, scalar, and fermionic particles. The alternative possibility of interpreting the Higgs scalars as bound states of the extra heavy fermions, as in technicolor models,²⁴ appears as an attractive minimalist approach. On the other hand, one can imagine a scenario where the GUT scale is quite close to the Planck scale, eliminating the hierarchy problem.¹³ This would be an interesting idea to pursue if no signal of supersymmetric particles is found.

5. Conclusions

We have extended presymmetry from fermions to bosons and consequently promoted the rather simple expansion of the SM with Dirac neutrinos to the symmetric model $SU(3)_q \times SU(3)_{\bar{q}} \times SU(2)_{q\bar{\ell}} \times SU(2)_{\bar{q}\ell} \times U(1)_Y \times \tilde{P}$ of separate color and weak gauge groups for quarks, leptons, and fermionic exotic partners. We have related the exotic symmetry \tilde{P} , which exchanges the new particles and the SM particles, with a residual presymmetry in the sense of Ekstein and its extension from matter to forces. Constraints from high precision experiments provide only restrictions on the mass of the new particles. The upper bounds below 1 TeV for fermion partners raise expectations of their direct detection. No fine-tuning should be required at the electroweak scale.

In order to go further, we mention that presymmetry and exotic symmetry apply to the forces of the SM implies duplication of $U(1)_Y$ within the gauge group $G_{q\bar{\ell}} \times G_{\bar{q}\ell} \times \tilde{P}$ with $G = SU(3) \times SU(2) \times U(1)$. However, under a full duplication of the SM, a residual presymmetry can also be realized through $G_{q\ell} \times G_{\bar{q}\bar{\ell}} \times \tilde{P}$, where now all SM particles are neutral with respect to the hidden gauge group $G_{\bar{q}\bar{\ell}}$ and \tilde{P} is the hidden symmetry exchanging ordinary and hidden partners; results on this alternative scenario will be reported elsewhere. Hidden sectors have been invoked frequently in extensions of the SM; for recent works see Ref. 25. This should be followed by a GUT for each G to have $(GUT)_{q\bar{\ell}} \times (GUT)_{\bar{q}\ell} \times \tilde{P}$ in the exotic case and $(GUT)_{q\ell} \times (GUT)_{\bar{q}\bar{\ell}} \times \tilde{P}$ in the more standard hidden possibility, unifying

standard and exotic or hidden partners and also strong and electroweak interactions. We note that a separation of GUT for ordinary quarks and leptons assures a proton stability. GUT predicts transitions between exotic and ordinary quarks and leptons leading to the decay of heavy exotic matter into ordinary matter, or transitions from heavy hidden matter to lighter hidden matter. From a cosmological point of view, this is a mandatory condition not to conflict with evidences on the absence of exotic or hidden baryons. To stabilize the hierarchy up to the GUT scale our model has to be embedded into, for example, a supersymmetric model, or eliminate the problem by joining the GUT and Planck scales. We also note that the well-known cosmological domain wall problems associated with the spontaneous breakdown of the discrete symmetry \tilde{P} may be solved via scattering of primordial black holes,²⁶ with no additional constraints on the model. Finally, we remark that the separation of electroweak and strong gauge interactions for ordinary and exotic or hidden partners opens the question of whether that somehow holds for gravity. Its answer would urge to know the gravitational properties of exotic or hidden matter.

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